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FINAL REPORT

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**MANAGEMENT PRACTICES TO OPTIMIZE SEED
PRODUCTION OF WINTERFAT**

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Management Practices to Optimize Seed Production of Winterfat
ADF contract 96000056

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Prepared by

M.P. Schellenberg, P.Ag

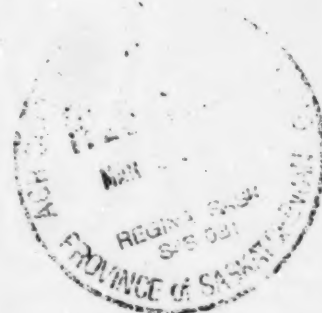
With the technical assistance of

J. Bolton

and

Statistical input of

Dr. F. Clarke



Management Practices to Optimize Seed Production of Winterfat

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(A) Summary: objectives of this project were: 1) to determine the effect of various harvesting methods on the seed yield of winterfat and 2) to determine the effects of seeding method and planting date on the establishment, forage and seed yield of winterfat. Purchase of seed was accomplished for 1997 seeding season. Hiring delays resulted in delays for seed preparation and seeder calibration. Seeding was completed for spring 1997 on 16 May for drill seeder, 02 June for broadcast seeder, and 16 June for air seeder. Broadcasting of the seed resulted in higher plant numbers than seeding with a drill. Seed delivery was improved by the addition of lime (Calcium fertilizer), wheat, or sand eliminating any obstructions in the delivery hose. A decline in seedling survival was noted when lime was added. The air seeder failed to deliver any seed due to seed flotation in seed tank. Conditioned seed without the bracts had improved establishment. Soil water was taken at seeding and monthly thereafter. The seeding treatments had no effect on soil water. Seedling emergence counts taken on 9 July, 7 August and 1 September indicated seedlings continued to emerge until 7 August. The results from a single seeding are inconclusive and due to late seeding impossible to separate seeding method from seeding date. Harvest methods ranked: Vacuum > hand stripping > flail > sickle in all three years.

Plots seeded in spring 1997 with the drill had greater numbers of seedlings surviving in 1998. Plots with bractless seed continued to have more plants present in 1998.

In the fall of 1997 broadcast seeding and drill seeding were completed after soil temperatures had fallen below 5 °C. Spring seeding occurred between 12 to 19 May 1998. Spring seeding resulted in greater emergence of winterfat than fall seeding for the 1998 season. Seeding with a drill resulted in fewer plants as did packing after broadcasting. Seed with bracts intact resulted in greater numbers. Soil water was greater in spring seeded plots and in plots seeded with the drill.

In the fall 1998 seeding commenced when soil temperatures had fallen below 5 °C which coincided with the period 10 to 13 November. Spring seeding for 1999 commenced 28 May and continued when adequate drying occurred between rain showers until 14 June. A large amount of precipitation has occurred the month of June and created problems with weed control. Weeds were an ongoing problem for 1999. Fall seeding for 1999 commenced on 2 November and was completed on 8 November. Spring seeding provided the greatest number of plants as did seed with bracts intact and broadcasting the seed.

In the fall 1999 seeding commenced when soil temperatures had fallen below 5 °C which coincided with the period 2 to 8 November. Spring seeding for 2000 commenced 17 May and was completed within a 2 week period. Moisture was not limiting in fall of 2000. A warming period was experienced during the winter and a sharp temperature decrease occurred in fall. Otherwise meteorological data was similar to previous years. For the year 2000 initially fall seeding provided more seedlings in spring but the effect had dissipated by fall. Having the bract intact continued to provide more seedlings and greater growth. By the following year the only factor having an impact was the date of seeding. One should note fall seeding was a significant factor for 1999 year of establishment site.

Year of seeding was significant for this study indicating a sensitivity to the

growing environment. Time of seeding appears to be year dependant. Seeding with bracts intact yields the most seedlings and dry matter yield. Broadcast seeding also yields more seedlings but packing following broadcasting had negative impact. Additive to improve seed flow had only early impact which dissipated by the second year.

Seed harvesting continued to follow trends established in previous years. Seed production continued to decrease. Sickle harvesting continued to result in declines of living plants. Analysis of combined year data indicates declining seed yield over the period of the experiment which might be attributable to climate and/or increased age of the stand. This requires further investigation.

(B) Executive summary: For 1997, spring broadcast seeding provided better establishment but better survival resulted from drill seeding. Air seeding of winterfat was not possible with present technology. Addition of lime, wheat, or sand carriers initially improved number of emerged seedlings initially. Only addition of wheat or sand provided a lasting benefit. Spring seeding of bractless seed resulted in higher seedling emergence and survival. Weed control will be needed in order to insure winterfat seed production is commercially viable.

For the 1998 experiment broadcasting, spring seeding date and seed with intact bracts resulted in the greatest numbers. Plots seeded with furrowing drill had greater soil moisture as did plots seeded in spring.

1999 resulted in a reversal of the 1998 seeding date impact. Broadcast seeding continued to result in best establishment.

2000 resulted in no difference between spring or fall seeded plots for number of plants. Intact seed (with bract) continued to result in greater number of seedlings. Broadcast seeding provided best establishment.

The following ranking of harvest methods according to seed yield is possible for the 1997 - 2000 harvest: Vacuum > hand stripping > flail > sickle. Vacuum and sickling yielded the larger amounts of additional inert material which had to be removed during the seed cleaning process. Sickling resulted in higher plant deaths.

Conclusions

Year of seeding was significant for this study indicating a sensitivity to the growing environment. Time of seeding (fall or spring) appears to be year dependant. Seeding with bracts intact yields the most seedlings and subsequent dry matter yield. Broadcast seeding also yields more seedlings but packing following broadcasting had a negative impact. The seeds do not tolerate any burying during the seeding process. Additive to improve seed flow had only early impact which dissipated by the second year.

The data supports use of weed barrier fabric for increased seed and plant production. The harvesting techniques can be ranked for seed yield as follows: vacuum > hand stripping > flail > sickling. This may be due to increased damage to plants resulting in a shift of resources from seed production to plant biomass. Seed production appears to be sensitive to climatic conditions and should be further investigated.

(C)Technical report: The objectives of this project were: 1) to determine the effect of various harvesting methods on the seed yield of winterfat and 2) to determine the effects of seeding method and planting date on the establishment, forage and seed yield of winterfat.

(Ci) Literature Review

Winterfat (*Krascheninnikovia lanata* (Pursh) Guldenstaedt. syn. *Ceratoides lanata* (Purse) JT Howell, syn. *Eurotia lanata* (Purse) Meq.) has been identified as being a potentially valuable species for ecological restoration (Romo et al 1995), erosion control (Van Dersal 1938, Stubbendieck et al. 1986) and winter forage for all livestock (Sampson 1924, USDA-FS 1937, Van Dersal 1938, Stubbendieck et al. 1986). Winterfat has been characterized as being salt loving (Sampson 1924, Van Dersal 1938), strong drought tolerance (USDA-FS 1937, Sampson 1924, Stubbendieck et al. 1986), a great seed producer (Van Dersal 1938) and highly fattening for cattle (USDA-FS 1937, Van Dersal 1938). A number of studies examining the chemical composition of winterfat indicate its superior winter feed quality (Clarke and Tisdale 1945, Smoliak and Bezeau 1967, unpublished data 1995). Clarke and Tisdale (1945) noted winterfat contained more protein and minerals and less crude fibre than did principle grasses of comparable growth stage. Protein and phosphorous content of winterfat was sufficient for livestock feeding on winter range (Smoliak and Bezeau 1967). With these attributes winterfat has created a great deal of interest among producers as a potential winter pasture forage. There are early recommendations to reseed native pasture to winterfat (Sampson 1924) for such purposes.

Extending grazing will likely result in reduced costs and greater returns to the producer (Adams et al. 1996). In a recent communication, extension agrologist J. Graham, indicated a potential 56% savings when cattle were pastured compared to maintaining them in a feedlot.

Seed availability is limited. Sources of seed with quantities sufficient to seed pastures are located to the south. The adaptability of this seed to Canadian conditions is not guaranteed. There is a licensed variety available in the U.S., 'Hatch', but it originates from New Mexico and assumed not adapted to the Canadian climate.

Presently research is ongoing for the development of an ecovar at Semiarid Prairie Agricultural Research Centre in co-operation with Ducks Unlimited and Dr. Romo, University of Saskatchewan. Dr. Romo also leads a research effort looking at the seedbed requirements and cold tolerance of winterfat seedlings (Romo et al. 1995).

To date the key hurdles facing forage and seed production of winterfat have been seed harvest and subsequent seeding. Demand presently outstrips the supply of seed adapted to the Canadian prairies. Presently, seed being used on the Prairies is presently harvested by hand (Big Sky Seeds pers. comm.) thus increasing costs. Due to physical seed characteristics (resembles a small cotton ball) seeding is difficult. Booth and Schuman (1983) recommend broadcasting seed, with bracts intact, at a shallow depth. Zabek and Romo (1995) broadcast the seed with a resulting plant density of 1.1 surviving plants m⁻². A higher plant density and row seeding pattern would be more desirable for seed production and harvest. This proposal addressed the questions of harvesting and seeding technologies.

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(Cii)

Winterfat Seeding Techniques and Season of Seeding

Objective: to determine the effects of seeding method and planting date on the establishment, forage and seed yield of winterfat.

Methods and Materials:

This study determined the effects of seeding method and planting date on the establishment of winterfat as well as forage and seed yield. To date, the recommendation for establishment of winterfat has been to broadcast the seed with the fluffy bracts intact. Row seeding plants for seed production facilitates mechanical harvest, fertilization, irrigation, and weed control. A factorial randomized block statistical design was chosen to look at alternatives to the above. The seeding methods included; (1) broadcast with packing (control), (2) drill and (3) broadcast without packing. The winterfat was seeded in two forms; (1) bracts intact and (2) bracts removed. To determine best seed delivery method the seed was seeded with (1) no additive, (2) cracked (inert) wheat, (3) sand and (4) fertilizer. The time of seeding was determined by comparing fall and spring seeding dates. To decrease the bias created by yearly climatic events the seeding was repeated over a three year period. Seed requirements required the annual purchase of seed. Data was collected on plant emergence, plant survival, plant density, plant heights, first production year dry matter yield and seed yield, and meteorological information. Soil water was monitored using a Time Domain Reflectometer to assist conclusions regarding establishment response.

Results and Discussion:

Meteorological Data

Precipitation was approximately 50mm for the months of May, July and August and 70 mm in June for 1997. September only received 15 mm. Evaporation exceeded precipitation and with June, July and August experiencing approximately 250 mm of evaporation each in 1997. (Figure 1a) Precipitation pattern for 1998 shows approximately 37 mm for May, July and August; September had 25 mm and June had 90mm. Overall 1998 was moister but a greater proportion fell in June. Evaporation was also greater for all months except June which realized a decrease in evaporation from 1997 of approximately 50 mm (Figure 1b). 1999 had greater precipitation in May, June and July but very little precipitation fell in August and as good as none in September. Evaporation was less than other years (Figure 1c). 2000 lost the greatest amount of moisture during the months of July and August. July 2000 had the greatest amount of rainfall. August 2000 had almost no rain. The month of September received 50 mm of rainfall making it one of the wetter falls since 1997. (Figure 1d). The year 2001 proved to be the driest year with almost no precipitation in fall (Figure 1e).

Mean maximum monthly temperatures indicate overall warmer temperatures for 1998 with a much earlier warming trend in spring (Figure 2a) than 1997. June, November and

December were the only months which were cooler in 1998 when compared to 1997. 1999 proved to be cooler than both 1998 and 1997 as already indicated by the Pan A Evaporation. 2000 was cooler yet with coldest months for the 4 year period for Feb, Nov and Dec. March and November were the only months in 1999 with a higher mean maximum monthly temperature. March and October were the only months 2000 that were above the previous years'. January and February had the lowest mean maximum for all years. The month of August for 2001 was the warmest. Mean minimum monthly temperatures showed a similar trend (Figure 2b). Minimum temperature for April was above 0°C in 1998, temperatures at which winterfat seed will germinate (Mohajery and Rasti 1995). November and December were the coldest in 2000. February 2001 was had the lowest mean minimum temperature for all years while September 2001 was the warmest.

Soil temperatures under grass at a depth of 5 cm indicate 1997 was the coolest year followed by 1999 and then 1998 with respective yearly average temperatures of 5.3, 5.9 and 6.9. For the winter months (January to March), 1998 was the warmest (Figure 3a) but 2000 was the warmest from 50 to 80 Julian days when previous years dropped. This trend continued for spring (April to May)(Figure 3b) and the summer months (June to August) (Figure 3c). 1999 had the coolest summer. For the fall months (September to December) 1999 proved the warmest (Figure 3d). Soil temperature dropped most sharply in fall 2000. The mean monthly soil temperatures at 10 cm indicate warmer temperatures in 2001 than the 39 year average (Figure 3e).

1997 Results

Spring of 1997 was the first season of seeding. Seeding occurred later than desired but soil water remained adequate. Seeding in spring of 1997 occurred 16 May for drill treatment and 2 June for broadcast seed. Seed flow was better with bracts removed. Seed flow was also improved with the addition of lime, sand and cracked wheat for both intact bracts and bract less. Seed delivery improved when obstructions were eliminated in the delivery hose. Seedling emergence counts suggest adding cracked wheat, sand or lime improved seedling emergence due to better seed placement. No clear benefits were detected for seed with or without bracts initially (Table 1). By final fall count, bractless seed plots had significantly higher populations (Table 1).

Broadcasting seed with intact bracts appears better than drilling the seed although initial separation of seeding method and date were not possible due to varied seeding dates. The confounding of seeding date with method makes it difficult to interpret these results. Broadcasting did result in higher plant numbers by fall (Table 1). An observation which seems contrary to present recommendations of earlier seeding date being better, broadcasting had a later seeding date. When you combine this observation with plants continuing to emerge until the 7 August plant count (Table 1) a possible explanation may be effect of seed source environment as noted in Abouguendia (1995) or winterfat has a higher germination temperature requirement (Mohajery and Rasti 1995).

Additives to the seed box initially had no effect but by fall plots seeded with wheat or sand additives had more seedlings. Lime initially had a beneficial effect but by fall a significant down turn in seedling numbers had occurred. (Table 1)

The seeding rate for spring 1997 did not result in the desired stand density and therefore a higher seeding rate was used in subsequent years.

On 28 May 1997 average soil water content was 16.7 % and on 3 June 1997 soil water content was 11.4 %. No statistically significant differences were evident in the soil moisture data for seed box additives or seed type. On 16 July 1997 plots in which the seed was broadcast had significantly more soil water. (Table 2)

To insure seeded winterfat becomes a commercially viable crop some type of weed control will be necessary. A great deal of time has been spent to hand remove weeds to maintain plots.

1998 Results

Data collected on 22 July 1998 (Table 3), for the experiment seeded in spring 1997, showed decreased populations when compared to numbers from the previous year (Table 1). A reversal of plants in drilled plots vs broadcast plots occurred. Plants in the drilled plots had fewer losses and greater production. Plots seeded with bracts intact seed continued to have fewer plants than plots seeded with bractless seed but dry matter production was higher for the first. Soil water data collected on 8 July indicated no significant differences between factors and had a mean soil water of 22%. Soil temperature also showed no significant differences with a mean surface soil temperature of 42°C. Plots with drill did have a furrow which may have provided improved microclimate or simply fewer weeds due to cultivation action when furrows were created .

Fall 1997 seeding occurred 6 November for both broadcast treatments, and 10-12 November for the drill. The soil temperature desired was 5°C or less and seeding did occur when this temperature was obtained for three days running, but due to seasonal fluctuations soil temperature did rise above this temperature for short periods. By spring 1998 furrows had refilled with soil eroded from adjacent areas as well as furrow rills. Spring 1998 seeding occurred 12 to 19 May for the broadcast treatments and 20 May for the drill treatments. Seed flow was as previously reported.

Numbers of plants emerging and surviving until fall 1998 indicate no additional emergence occurred during the growing season.(Table 4) Fall seeding resulted in significantly fewer plants in contrast to spring seeding. Broadcasting seed resulted in significantly more seedlings than drill seeding, as in 1997. Broadcasting seed without packing resulted in significantly more seedlings than broadcasting followed by packing. Seeds with bracts intact yielded significantly more seedlings than bractless seed. Additives in the seed box to improve seed flow had no effect on number of seedlings.

Plants had significantly more growth, as indicated by plant height, when seeded in fall (Table 4). This would suggest the possibility that emergence had occurred earlier which may have been detrimental in 1998's dry spring. Plants seeded with the drill had decreased growth when compared to broadcast seed (Table 4). Packing in conjunction with broadcasting had no effect on growth. Seeds with bracts intact also significantly out grew bractless seed. Additives in the seed box to improve seed flow had no effect on seedling growth.

Desired stand densities were not realized despite attempts to increase seeding rate. Seeders were adjusted to allow maximum amount of seed.

Soil water in the top 15 cm (Table 5) fluctuated throughout the 1998 growing season.

Earlier soil water was lower than 1997 (Table 2) but the October measurement was higher in 1998. Plots seeded in spring 1998 (Table 5) had significantly more soil moisture than plots seeded in fall. Again, if seedlings emerged earlier then soil water would have been utilized despite possible seedling die off. Also plots seeded with the drill had significantly more moisture throughout the growing season. Packing following broadcasting had no beneficial effect. Additives or seed with or without bracts had no impact on soil moisture.

1999 Results

In the fall 1998 seeding commenced when soil temperatures had fallen below 5 ° C which coincided with the period 10 to 13 November. Spring seeding for 1999 commenced 28 May and continued when adequate drying occurred between rain showers until 14 June. A large amount of precipitation has fallen in the month of June and created problems with weed control. Weeds were an ongoing problem for 1999.

Plant count and plant density data (Table 6) indicates a reversal in benefit of time of seeding. 1999 spring seeding resulted in significantly greater number of plants than seeding in the 1998 fall. This reversal suggests an environment interaction. Fall seeded plots had a 13.8% loss from the first plant count to the second while spring seeded plots had a 61% increase. Bract intact seed continued to result in significantly greater number of plants. Plots seeded with seed with bracts maintained the same number of plants while bractless plots increased 31%. Drilling the seed failed to provide any benefit. Broadcasting the seed resulted in greater number of plants but packing after broadcasting did not result in additional plants. Additives to improve flow of seed failed to increase the number of plants above the number of plants resulting from no additives.

Plant growth, indicated by plant height, was higher for fall seeded plots. Spring seeded plots had more rapid growth with a 132% increase from initial measurement compared to 82% for fall seeded plots. Fall seeded plots growth may have been due to earlier germination than fall seeded plots. No other treatments has any effect on growth.

Soil moistures in Table 7 indicate the spring moisture conditions for 1999 were wetter than previous years. By August the moisture had dissipated with conditions most likely approaching permanent wilting point by September. Unfortunately the soil had dried to the point the TDR probes could not be inserted in October to verify. Plots which were drilled retained more moisture. This may have been due in part to lack of plants (Table 6) to access the resource as well as the furrows providing a microclimate effect. Additives failed to provide any effect on soil moisture as in previous years.

A final site was seeded 8-10 Nov 2000.

2000 Results

In the fall of 1999 seeding commenced 2 November and proceeded until 8 November. Spring seeding took place over a 2 week period starting 17 May 2000. Weeds continued to be an issue for 2000. Early control was achieved but the July flush was undeterred by efforts to control weed populations.

Plant counts for the site seeded in fall 1998 and spring 1999 (S98-99) were taken on 10

July along with plant heights. Date of seeding had significant impact on plant height with fall seeded plants having more plant height but plant densities were higher for spring seeded plots. Densities greater than target population of 1 per meter. Drilling the seed continued to have negative effect for the number of plants with packing having no effect for number of plants or plant growth. Any effect due to additives had dissipated by 2000. Seed with bract intact had slightly more than twice the number of plants present. (Table 8) Soil water was assessed 19 June, 25 July and 23 August with average % volume being 27.1, 19.8, and 8.3 respectively. The only statistical difference occurred for seed type on the final date but the difference of 0.1% was not biologically significant.

For the site seeded fall 1999 and spring 2000 (S99-00) plant counts and plant height measurements occurred 13 July and 25 August (Table 9). Fall seeding date resulted in the larger plants and greater number of plants but by the second measurement date this effect was gone. Drilling the seed had a negative impact on seedling number and plant height. Packing initially had a positive effect but by the second date a negative effect was noted. Packing had no impact on rate of growth. Additives had no effect. Seed with the bracts intact continued to provide faster growth and more seedlings. Percent of pure live seeds densities were similar to previous years. Emerging plants were lower for S99-00 than S98-99 but seedling numbers continued to increase as the growing season progressed as opposed to decreasing as observed for S98-99.

More soil water was available during the early summer (Table 10) in drilled plots as a result of furrowing effect. Soil moisture measurements taken 21 June, 26 July, 25 August and 11 October averaged 21.9%, 16.2%, 8.7% and 16.8% respectively. Impact of fall rains are evident in the higher October readings.

Per plant dry matter yields (Table 11) for material harvested in 1999 (S97-98) and 2000 (S98-99) suggest 1999 was better year for growth for fall seeded plots with a 1/3 higher yield. There was little or no impact for spring seeded plots. Whether the bract was intact or not at time of seeding had no impact on yields. Method of seeding had no impact on plant production. For S97-98 plots seeded with no additive were significantly more productive than plots seeded with additives but no differences were noted for S98-99. S98-99 overall had lower production than S97-98, possibly as a result of more plants in the plot therefore decreased access to resources.

2001 Results

For seeded in fall 1999 and spring 2000 time only impacted height with the 2000 seeding being taller. Broadcast seed continued to have more plants. The use of additives had no effect. (Table 12). The difference in height translated in a significant difference in dry matter yield as well, with plants seeded in spring 2000 yielding 17.5 gm per plant while plants seeded in fall of 1999 only yielded 7.5 gm (data not shown). The first soil moisture reading indicated more moisture in plots seeded in spring 2000 (21.3%) as opposed to plots seeded in fall 1999 (19.5%). This may partially explain the increased growth. No other factors resulted in significantly different reading at any of dates; 31 May (20.3% average), 28 June (12.6% average) and 2 August (14.8% average).

The plots seeded in fall 2000 had more plants in plots with intact seed and broadcast seed with no packing. Drilling and packing had negative effects, although initially there appeared a

height advantage for plants drilled. (Table 13) The plots were clipped 10 September. No yield differences were found with an average dry matter per plant of 4.0 gm. No factor differences were noted for soil moisture reading for 1 June (20.7% average), 28 June (12.7% average) and 2 August (16.6% average).

Combined Years

Combining data for S97-98 (fall seeded 97, spring seeded 98), S98-99 and S99-00 (Table 14) indicates the year was significant for dry matter yield, establishment year fall count. This is not surprising when one examines the differences in the meteorological data, increasing dryness from 1998 to 2000. Seeding in the fall with bracts intact provided the greatest success but there was some year to year variation; ie 1997. The time of seeding was not significantly different for the second year plant counts. Intact bracts and seeding method were significant for establishment fall plant count. Broadcasting had triple the number of seedlings in the establishment fall counts. Packing after broadcasting had a negative impact with a 12% reduction in seedling numbers for establishment year fall counts but the difference was not there for the second year. Although combined data does not show a significant difference for dry matter yield for seeder, broadcast seeding had more seedlings. Packing tended to have negative impact on number of seedlings. The additive had only an early effect which dissipated by the second year.

Looking at the years individually one notes benefits for fall or spring seeding may be climate dependant and should be further investigated. For S97-98 spring seeding was advantageous, for S98-99 fall seeding resulted in the highest number of seedlings, but with S99-00 both seeding times produced similar seedling numbers. Also young plants' dry matter yields were impacted by the year as to a higher degree than were the more mature plants in the seed harvest study. This should warrant further study.

Conclusion

Time of seeding (fall or spring) appears year dependant and only noticeable during the year of seeding. Seeding with bracts intact yields the most seedlings and dry matter yield. Broadcast seeding also yields more seedlings but packing following broadcasting had negative impact. Additive to improve seed flow had only early impact which dissipated by the second year.

Table 1: Winterfat seedling plant counts, plant height and plant density for spring 1997 seeding. Statistical analysis performed on square root plus one transform to decrease variable. Reported values have been converted to untransformed values.

	Plant Count (per plot)				
Factor	9 July	7 August	1 September	Plant Height (cm)	Plant Density (Plants m ⁻²)
Seeder					
Drill	0.8	1.6	1.4	33.8	0.1
Broadcast	1.7	2.8	2.8	35.8	0.2
Additive					
None	0.3	1.4	1.6	32.9	0.1
Lime	1.5	2.0	1.0	35.8	0.1
Wheat	1.4	2.6	2.6	35.5	0.2
Sand	1.7	3.0	3.0	34.4	0.2
Seed Type					
Bract	0.7	1.8	1.3	34.1	0.1
Bractless	1.8	2.6	2.8	35.3	0.2
CV (%)	46	38	32	24	5.9
Contrasts					
Drill vs Broadcast	ns ^b	0.04	0.01	ns	0.02
Bract vs no Bract	ns	ns	0.01	ns	0.01
No additive vs Additive	ns	ns	ns	ns	ns
Lime vs wheat, sand	ns	ns	0.01	ns	0.01
Wheat vs Sand	ns	ns	ns	ns	ns

^a - pure live seed, ^b - not significant (P>0.05)

Table 2: Soil water for the top 15 cm as determined using a time domain reflectometer for the growing season of 1997. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been converted to untransformed values.

Factor	Soil Water (%)			
	16 July	2 August	19 September	20 October
Seeder				
Drill	23.3*	22.7	20.1	15.9
Broadcast	24.3	23.2	18.6	15.6
Additive				
None	22.6	21.7	21.3	14.5
Lime	23.7	24.1	17.8	15.4
Wheat	24.3	24.7	18.8	14.7
Sand	24.2	21.4	20.1	15.6
Seed type				
Bract	24.9	23.0	19.5	15.1
No Bract	22.5	23.0	19.5	15.1
CV %	9.1	9.9	11.9	11.6
Contrast				
Lime vs Wheat, Sand	ns	ns	ns	ns
Wheat vs Sand	ns	ns	ns	ns

* - Statistically significant ($P > 0.05$), ns - Statistically not significant ($P > 0.05$).

Table 3: Number of plants surviving winter, plant height, individual plant dry matter yield and plant density for site seeded in spring 1997. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been converted to untransformed values.

Factor	Plant Count (Per plot)	Plant height (cm)	Dry matter yield (gm plant ⁻¹)	Plant Density (plants/m ⁻²)
Seeder				
Drill	0.4*	25.8*	15.6*	0.028*
Broadcast	0.1	9.1	2.8	0.003
Additive				
None	0.2	10.2	8.4	0.011
Lime	0.2	21.5	7.5	0.013
Wheat	0.2	24.5	10.9	0.010
Sand	0.5	17.8	13.3	0.034
Seed type				
Bract	0.1	20.1	11.5	0.010
No Bract	0.4	16.6	8.5	0.025
CV %	13.3	70.8	68.4	1.3
Contrast				
No additive vs Additive	ns	ns	ns	ns
Lime vs Wheat, Sand	ns	ns	ns	ns
Wheat vs Sand	s	ns	ns	s

* , s - Statistically significant ($P > 0.05$), ns - Statistically not significant ($P > 0.05$).

Table 4: Winterfat seedling plant counts, plant height and plant density for site seeded in fall 1997 and spring 1998. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been converted to untransformed values.

Factor	Plant Count (per plot)		Plant Height (cm)		Plant Density (Plants/m ²) 16 Sept.
	3 July	16 Sept	3 July	16 Sept	
Seeding Date					
Fall '97	1.1	1.2	23.8*	28.4*	0.07
Spring '98	3.3*	2.9*	18.6	19.6	0.19*
Seeder					
Drill	0.9	1.0	19.4	22.7	0.06
Broadcast & no pack	3.2	2.9	22.4	25.5	0.18
Broadcast & pack	2.5	2.3	21.7	23.9	0.14
Additive					
None	2.3	2.1	22.6	24.9	0.13
Lime	2.0	1.9	20.3	24.2	0.13
Wheat	2.1	2.0	22.0	24.4	0.14
Sand	2.5	2.2	19.8	22.7	0.12
Seed Type					
Bract	3.1*	2.9*	22.8*	25.9*	0.18*
Bractless	1.3	1.3	19.4	22.2	0.08
CV (%)	19.3	18.0	12.8	13.1	3.2
Contrasts					
Drill vs Broadcast	s	s	s	s	s
Packer vs No Packer	s	s	ns	ns	s
No additive vs Additive	ns	ns	s	ns	ns
Lime vs wheat, sand	ns	ns	ns	ns	ns
Wheat vs Sand	s	ns	ns	ns	ns

^a - pure live seed, ^b - not significant (P>0.05), * or s - significant (P>0.05).

Table 5: Soil water for the top 15 cm as determined using a time domain reflectometer for the growing season of 1998 for site seeded in fall 1997 and spring 1998. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been converted to untransformed values.

Factor	Soil Water (%)			
	9 July	10 August	11 September	10 October
Time				
Fall '97	19.4	11.9	9.8	17.6
Spring '98	20.8*	13.7*	11.8*	19.2*
Seed type				
Bract	20.2	12.9	10.5	18.0
No Bract	19.9	12.7	11.1	18.7
Seeder				
Drill	21.7	14.5	13.5	19.6
Broadcast, no pack	19.1	12.0	9.0	17.6
Broadcast with pack	19.5	11.8	9.9	17.9
Additive				
None	20.3	12.2	10.4	18.4
Lime	21.5	13.8	11.9	18.4
Wheat	19.5	12.5	9.9	18.9
Sand	19.1	12.8	10.9	17.8
CV %	6.8	10.0	10.2	6.1
Contrast				
Drill vs Broadcast	s	s	s	s
Packer vs No Packer	ns	ns	ns	ns
No Additive vs Additive	ns	ns	ns	ns
Lime vs Wheat, Sand	ns	ns	s	ns
Wheat vs Sand	s	ns	ns	ns

* , s- Statistically significant ($P>0.05$). ns - Statistically not significant ($P>0.05$)

Table 6: Winterfat seedling plant counts, plant height and plant density for site seeded in fall 1998 and spring 1999. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been converted to untransformed values.

Factor	Plant Count (per plot)		Plant Height (cm)		Plant Density (Plants/m ²) 10 Aug.
	14 July	10 Aug	14 July	10 Aug	
Seeding Date					
Fall '98	60.1*	51.8*	18.3*	33.4*	0.14*
Spring '99	22.8	36.7	8.5	19.8	0.10
Seeder					
Drill	18.5	21.4	12.8	26.2	0.07
Broadcast & no pack	53.8	55.4	13.7	27.0	0.16
Broadcast & pack	52.1	56.0	13.7	26.6	0.16
Additive					
None	39.6	42.8	13.5	24.8	0.13
Lime	45.3	45.4	14.0	27.5	0.14
Wheat	41.0	43.1	12.8	26.3	0.13
Sand	40.0	45.7	13.3	27.7	0.14
Seed Type					
Bract	67.2*	67.9*	13.7	26.4	0.17*
Bractless	15.7	20.6	13.2	26.8	0.09
CV (%)	46.5	35.1	25.5	19.1	3.9
Contrasts					
Drill vs Broadcast	s	s	ns	ns	s
Packer vs No Packer	ns	ns	ns	ns	ns
No additive vs Additive	ns	ns	ns	ns	ns
Lime vs wheat, sand	ns	ns	ns	ns	ns
Wheat vs Sand	s	ns	ns	ns	ns

^a - pure live seed, ^b - not significant (P>0.05), * or s - significant (P>0.05).

Table 7: Soil water for the top 15 cm as determined using a time domain reflectometer for the growing season of 1999 for site seeded in fall 1998 and spring 1999. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been converted to untransformed values.

Factor	Soil Water (%)		
	30 June	20 July	25 August
Time			
Fall '98			
Spring '99	25.0	24.0	9.8
Seed type	24.9	23.2	9.3
Bract	25.0	23.7	9.6
No Bract	24.9	23.6	9.5
Seeder			
Drill	25.8	25.2	9.8
Broadcast, no pack	24.1	22.9	9.2
Broadcast with pack	25.0	22.8	9.6
Additive			
None	24.1	23.8	9.7
Lime	25.3	23.5	9.5
Wheat	25.3	24.2	9.5
Sand	25.0	23.2	9.4
CV %	5.0	4.8	8.6
Contrast			
Drill vs Broadcast	s	s	ns
Packer vs No Packer	ns	ns	ns
No Additive vs Additive	ns	ns	ns
Lime vs Wheat, Sand	ns	ns	ns
Wheat vs Sand	ns	ns	ns

* , s- Statistically significant ($P > 0.05$), ns - Statistically not significant ($P > 0.05$)

Table 8: Winterfat seedling plant counts, plant height and plant density for site seeded in fall 1998 and spring 1999. Data collection one year later 10 July 2000. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been back transformed.

Factor	Plant Count (per plot)	Plant Height (cm)	Plant Density (Plants/m ²)
Seeding Date			
Fall '98	35.5	33.0*	1.7
Spring '99	29.3	26.1	1.9*
Seeder			
Drill	18.7	29.3	0.8
Broadcast & no pack	45.3	28.8	2.2
Broadcast & pack	48.2	30.7	2.2
Additive			
None	40.2	28.8	1.9
Lime	38.4	29.7	1.7
Wheat	32.7	29.7	1.6
Sand	38.3	30.2	1.9
Seed Type			
Bract	54.5*	30.3	2.2*
Bractless	20.3	28.9	1.4
CV (%)	29.7	10.6	17.3
Contrasts			
Drill vs Broadcast	s	ns	s
Packer vs No Packer	ns ^b	ns	ns
No additive vs Additive	ns	ns	ns
Lime vs wheat, sand	ns	ns	ns
Wheat vs Sand	ns	ns	ns

^a - pure live seed, ^b ns - not significant (P>0.05), *or s - significant (P>0.05).

Table 9: Winterfat seedling plant counts, plant height and plant density (standardized according to seeding rate) for site seeded in fall 1999 and spring 2000. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been back transformed.

Factor	Plant Count (per plot)		Plant Height (cm)		Plant Density (Plants/m ²) 25 Aug.
	13 July	25 Aug	13 July	25 Aug	
Seeding Date					
Fall '99	17.9*	30.7	16.5*	32.1	0.15
Spring '00	8.2	33.3	8.3	17.1	0.10
Seeder					
Drill	4.3	10.1	13.1	25.2	0.04
Broadcast & no pack	15.7	46.8	11.7	24.3	0.14
Broadcast & pack	19.2	39.2	12.4	24.2	0.18
Additive					
None	12.2	32.8	11.8	24.4	0.19
Lime	14.0	31.2	12.0	25.0	0.10
Wheat	13.6	33.5	12.6	24.6	0.10
Sand	12.4	30.6	13.0	24.5	0.09
Seed Type					
Bract	17.8*	45.2*	12.4	24.7	0.12
Bractless	8.3	18.8	12.3	24.5	0.13
CV (%)	35.2	26.0	16.7	12.9	8.7
Contrasts					
Drill vs Broadcast	s ^b	s	ns	ns	s
Packer vs No Packer	s	s	ns	ns	ns
No additive vs Additive	ns	ns	ns	ns	ns
Lime vs wheat, sand	ns	ns	ns	ns	ns
Wheat vs Sand	ns	ns	ns	ns	ns

^a - pure live seed, ^b ns- not significant (P>0.05), * or s - significant (P>0.05).

Table 10: Soil water for the top 15 cm as determined using a time domain reflectometer for the growing season of 2000 for study seeded fall 1999 and spring 2000. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been back transformed.

Factor	Soil Water (%)			
	21 June	26 July	25 August	11 October
Seeding Date				
Fall '99	21.9	16.4	8.7	16.7
Spring '00	21.8	16.0	8.8	16.9
Seeder				
Drill	24.0	17.1	8.9	16.3
Broadcast	20.3	15.8	8.8	16.7
Broadcast with pack	21.3	15.8	8.5	17.4
Additive				
None	21.6	15.9	8.9	16.7
Lime	22.4	22.4	8.8	16.6
Wheat	22.3	16.1	8.9	16.8
Sand	21.3	15.8	8.4	17.1
Seed type				
Bract	21.8	16.2	8.7	16.6
No Bract	22.0	16.2	8.8	17.0
CV %	5.3	6.4	6.6	4.7
Contrast				
Drill vs Broadcast	s	s	ns	ns
Packer vs No Packer	ns	ns	ns	ns
No additive vs Additive	ns	ns	ns	ns
Lime vs wheat, sand	ns	ns	ns	ns
Wheat vs Sand	ns	ns	ns	ns

* - Statistically significant ($P > 0.05$), ns - Statistically not significant ($P > 0.05$).

Table 11: Per plant-dry matter yields for sites seeded in fall 1997 and spring 1998 (S97-98) and fall 1998 and spring 1999 (S98-99). Harvest occurred in July of 1999 and 2000 respectively. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been back transformed.

Factor	S97-98 (gm plant ⁻¹)	S98-99 (gm plant ⁻¹)
Seeding date		
Fall	20.2*	14.3*
Spring	9.4	8.4
Seed type		
Bract	13.1	12.3
No Bract	16.5	10.4
Seeder		
Drill	12.8	11.6
Broadcast, no pack	14.6	10.6
Broadcast with pack	17.1	11.8
Additive		
None	21.0	11.6
Lime	13.9	10.7
Wheat	11.7	10.9
Sand	12.7	12.2
CV %	39.2	23.9
Contrast		
Drill vs Broadcast	ns	ns
Packer vs No Packer	ns	ns
No Additive vs Additive	s	ns
Lime vs Wheat, Sand	ns	ns
Wheat vs Sand	ns	ns

* , s- Statistically significant (P>0.05), ns - Statistically not significant (P>0.05)

Table 12: Winterfat seedling plant counts, plant height and plant density (expressed as percent of pure live seed m^{-2}) for site seeded in fall 1999 and spring 2000. Data was collected 23 July 2001. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been back transformed.

Factor	<u>Plant Count (per plot)</u>	<u>Plant Height (cm)</u>	<u>Plant Density (Plants/m^{-2})</u>
Seeding Date			
Fall '99	0.7	27.6	0.06
Spring '00	0.9	33.8*	0.04
Seeder			
Drill	0.3	30.9	0.02
Broadcast & no pack	1.1	30.3	0.07
Broadcast & pack	1.0	30.8	0.06
Additive			
None	0.9	30.3	0.06
Lime	0.7	30.8	0.05
Wheat	0.8	30.5	0.05
Sand	0.8	31.0	0.05
Seed Type			
Bract	1.1*	30.4	0.07*
Bractless	0.5	30.8	0.03
CV (%)	16.8	13.9	2.0
Contrasts			
Drill vs Broadcast	s	ns	s
Packer vs No Packer	ns	ns	ns
No additive vs Additive	ns	ns	ns
Lime vs wheat, sand	ns	ns	ns
Wheat vs Sand	ns	ns	ns

^a - pure live seed, ^b ns- not significant ($P>0.05$). *or s - significant ($P>0.05$).

Table 13: Winterfat seedling plant counts, plant height and plant density (expressed as percent of pure live seed m^{-2}) for site seeded in fall 2000. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been back transformed.

Factor	<u>Plant Count (per plot)</u>		<u>Plant Height (cm)</u>		<u>Plant Density (Plants m^{-2})</u>	
	25 July	10 Aug	25 July	10 Aug	25 July	10 Aug
Seeder						
Drill	0.4	0.5	28.9	29.9	0.03	0.03
Broadcast & no pack	0.7	0.80	25.6	27.6	0.05	0.05
Broadcast & pack	0.3	0.5	26.0	26.6	0.03	0.02
Additive						
None	0.6	0.6	26.5	26.1	0.04	0.04
Lime	0.5	0.6	28.7	28.7	0.03	0.04
Wheat	0.5	0.6	25.1	29.7	0.03	0.04
Sand	0.4	0.6	27.1	27.5	0.03	0.04
Seed Type						
Bract	0.6*	0.7*	26.6	28.3	0.04*	0.05*
Bractless	0.4	0.4	27.1	27.7	0.02	0.02
CV (%)	11.3	13.2	9.2	11.0	1.1	1.4
Contrasts						
Drill vs Broadcast	ns	ns	s	ns	ns	ns
Packer vs No Packer	s	s	ns	ns	s	s
No additive vs Additive	ns	ns	ns	ns	ns	ns
Lime vs wheat, sand	ns	ns	ns	ns	ns	ns
Wheat vs Sand	ns	ns	s	ns	ns	ns

^a - pure live seed, ^b ns- not significant ($P>0.05$), *or s - significant ($P>0.05$).

Table 14: Winterfat fall seedling plant counts for establishment year and year 2, and dry matter yield (per plant) across sites: S97-98 (fall 97, spring 98), S98-99, S99-00. Spring 97 and fall 2000 omitted due to single seeding date. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been back transformed.

	<u>Establishment yr (m⁻¹)</u>	<u>Year 2 (m⁻¹)</u>	<u>Dry Matter yield yr2 (gm plant⁻¹)</u>
Factor			
Site			
S97-98	2.1	0.8	14.8*
S98-99	2.1	1.8*	11.3
S99-00	1.6*	0.9	12.5
Seeding Date			
Fall	1.7	1.1	17.3*
Spring	2.2*	1.2	8.4
Seeder			
Drill	0.9	0.6	12.8
Broadcast & no pack	2.6	1.5	12.4
Broadcast & pack	2.3	1.4	13.4
Additive			
None	1.9	1.2	15.1
Lime	1.9	1.1	11.9
Wheat	2.0	1.1	11.7
Sand	1.9	1.2	12.8
Seed Type			
Bract	2.5*	0.9	12.1
Bractless	1.4	1.5*	13.7*
CV (%)	19.3	16.2	33.6
Contrasts			
Drill vs <u>Broadcast</u>	s	s	ns
Packer vs No <u>Packer</u>	ns	ns	ns
No additive vs <u>Additive</u>	ns	ns	ns
Lime vs <u>wheat, sand</u>	ns	ns	ns
Wheat vs <u>Sand</u>	ns	ns	ns

^a - pure live seed, ^b ns- not significant (P>0.05), *or s - significant (P>0.05).

Figure 1a: Precipitation and Pan A evaporation for the 1997 growing season.

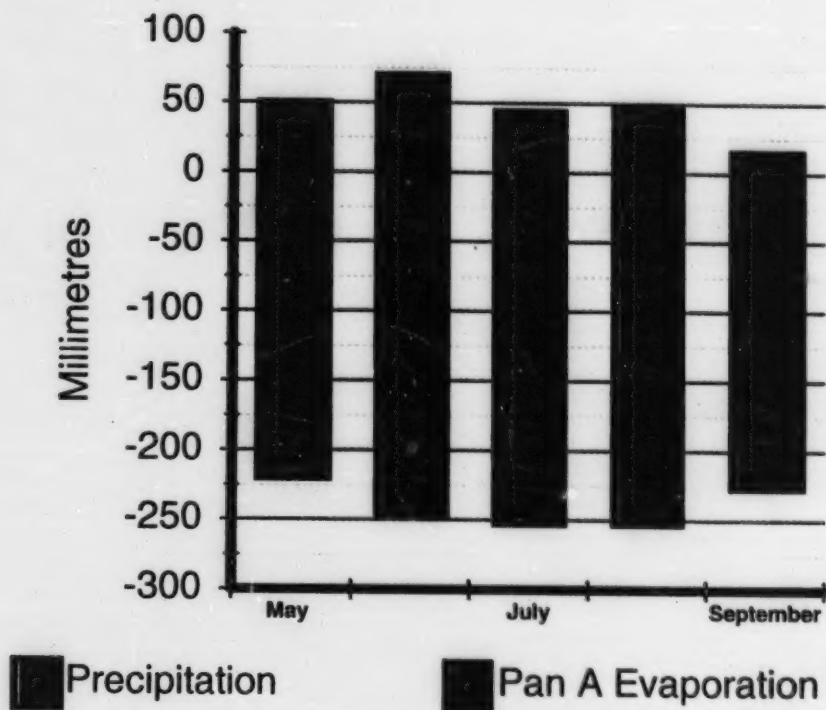


Figure 1b: Precipitation and Pan A evaporation for the 1998 growing season.

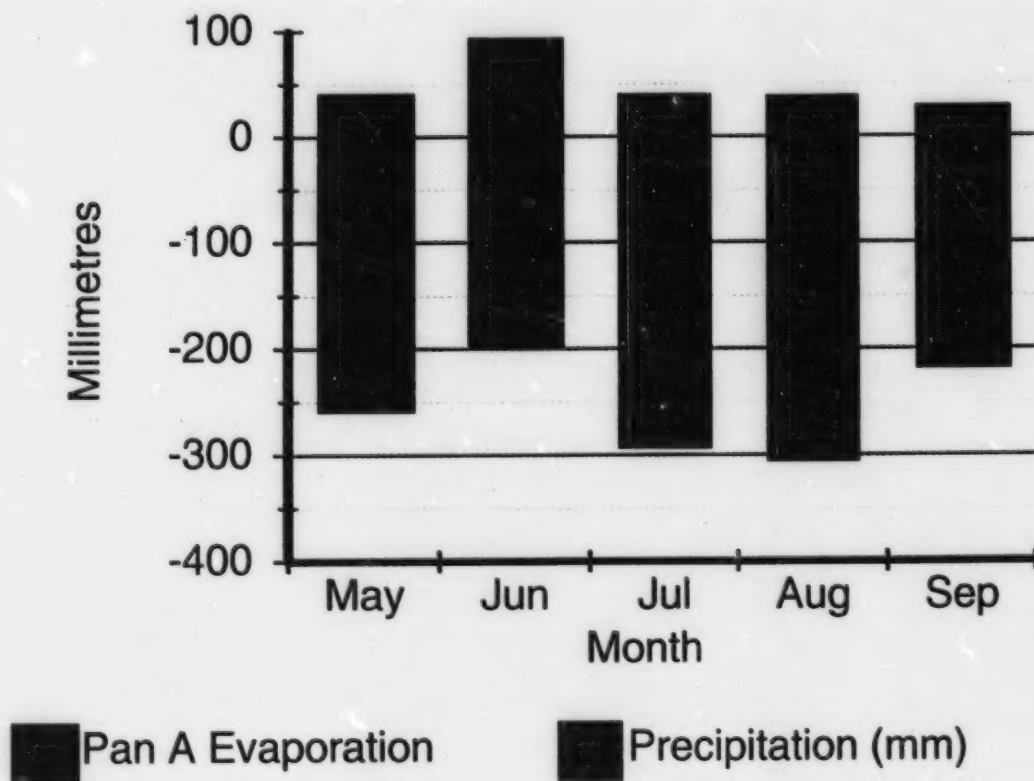


Figure 1c: Precipitation and Pan A evaporation for the 1999 growing season.

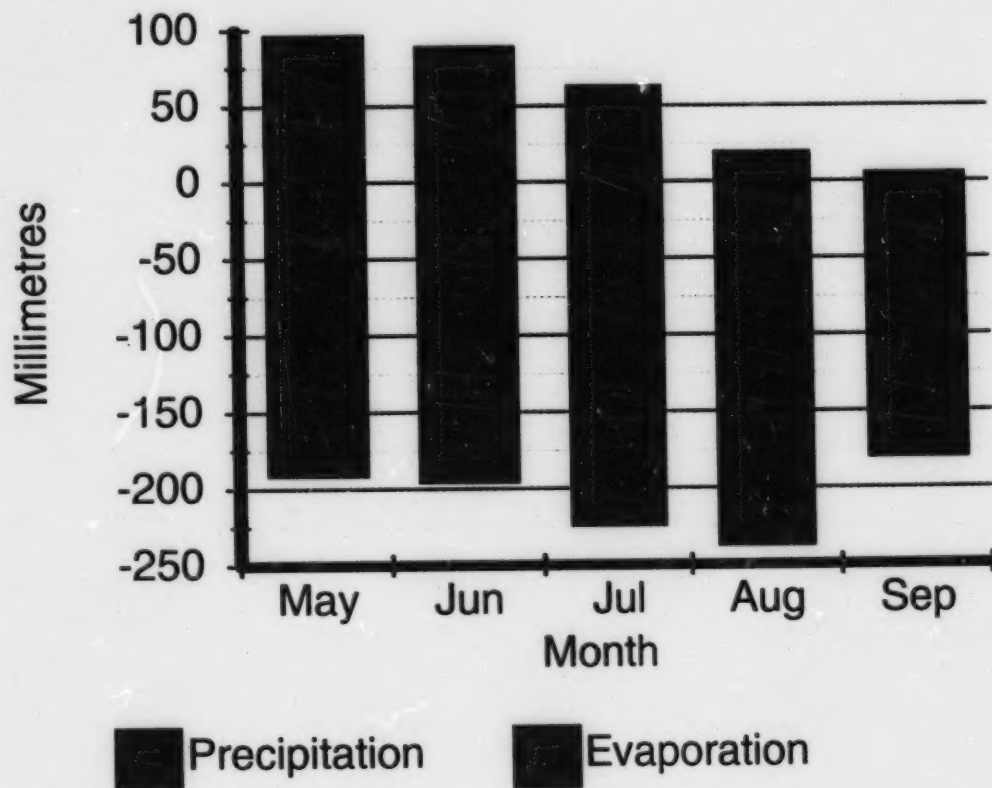


Figure 1d: Precipitation and Pan A evaporation for the 2000 growing season.

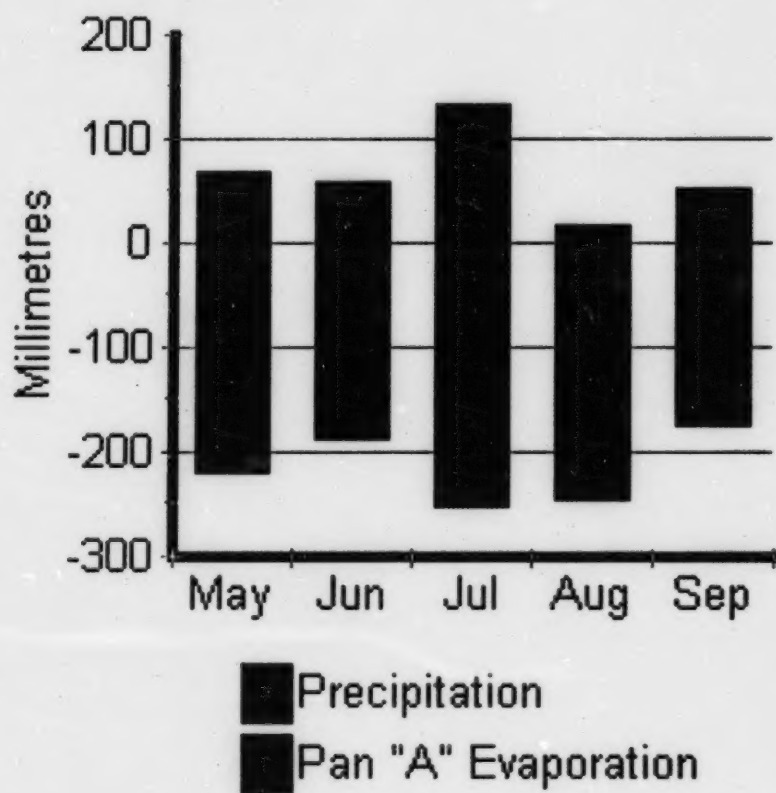


Figure 1e: Precipitation and Pan A evaporation for the 2001 growing season.

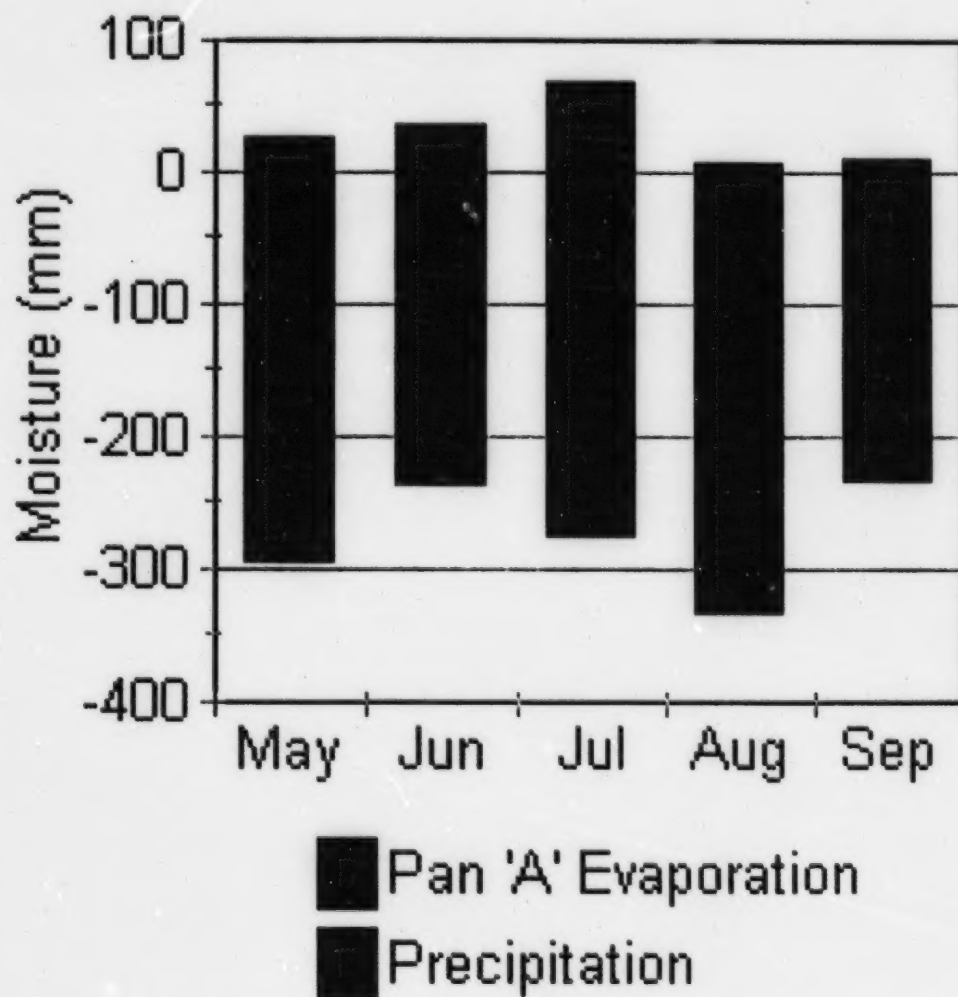


Figure 2a: Mean Monthly Maximum Temperature (°C) for 1997 to 2001.

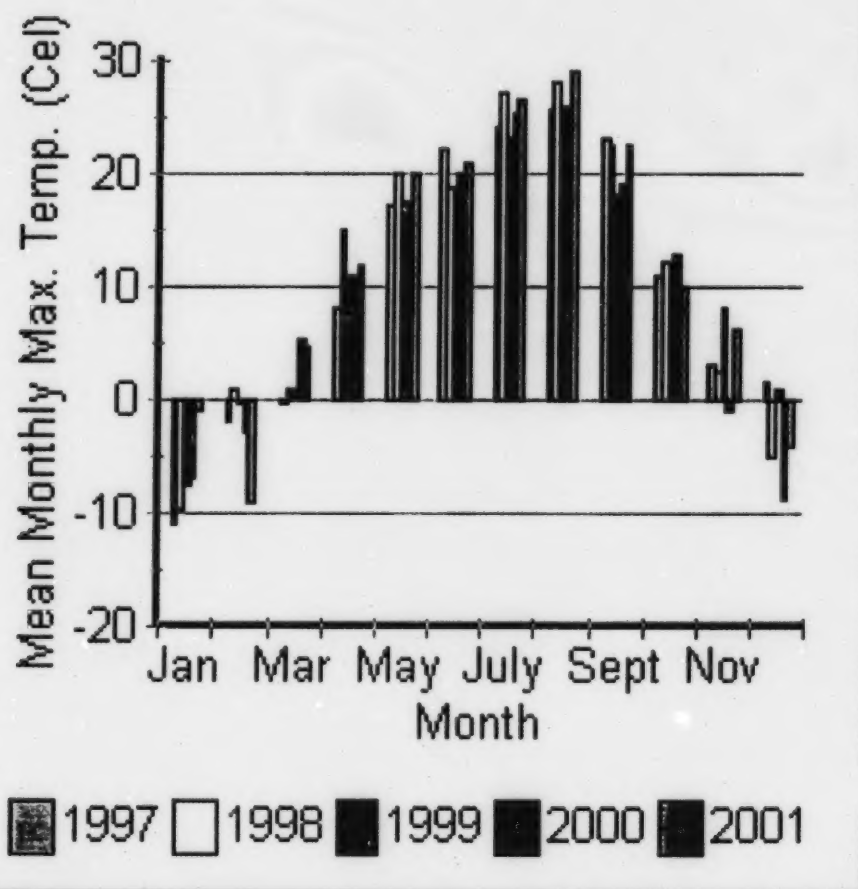


Figure 2b: Mean Monthly Minimum Temperature (°C) for 1997 to 2001.

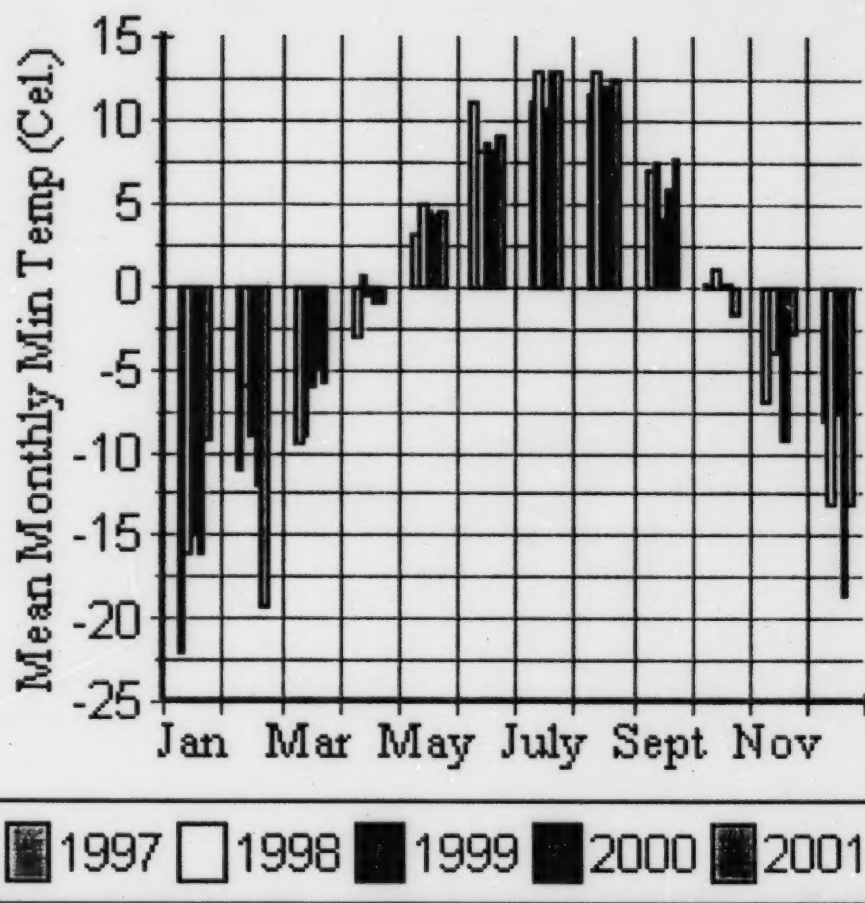


Figure 3a: Daily average soil temperatures under grass at a depth of 5 cm for the winter months (January to March) for 1997 to 2000.

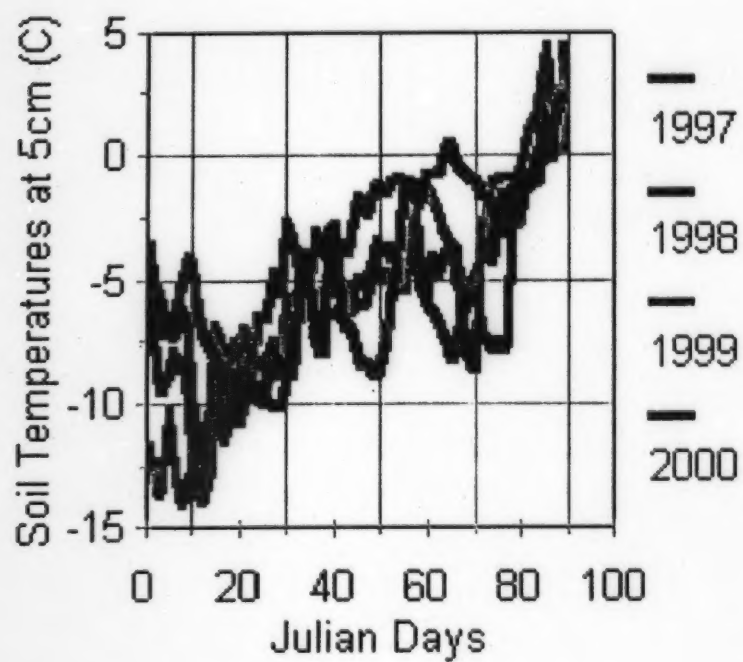


Figure 3b: Daily soil temperatures under grass at a depth of 5 cm for the spring months (April to May) for 1997 to 2000.

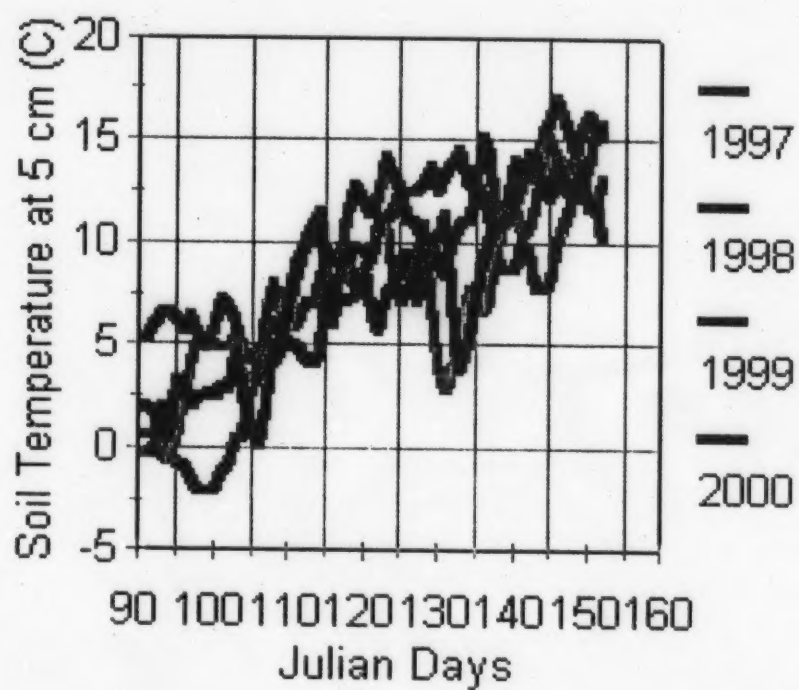


Figure 3c: Daily average soil temperatures under grass at a depth of 5 cm for the summer months (June to August) for 1997 to 2000.

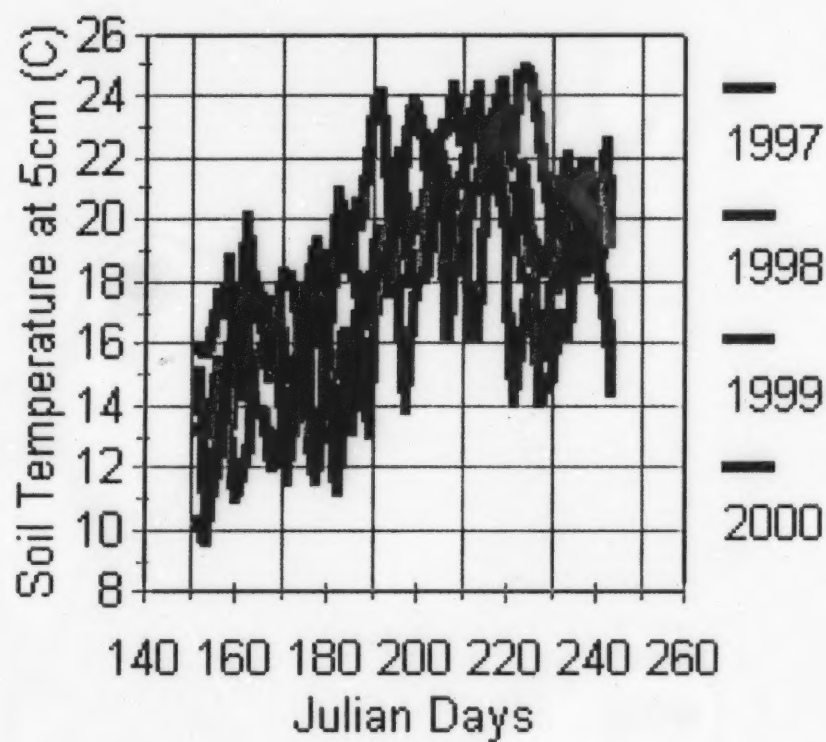


Figure 3d: Daily average soil temperatures under grass at a depth of 5 cm for the fall months (September to December) for 1997 to 2000.

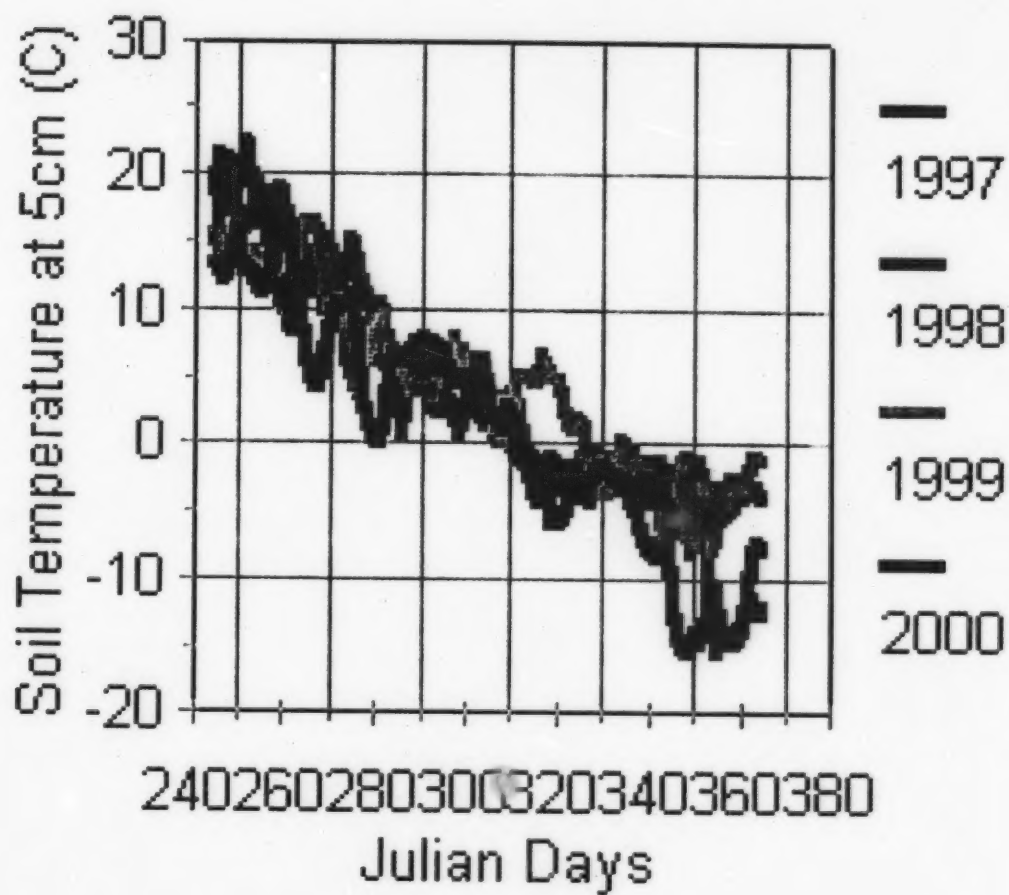
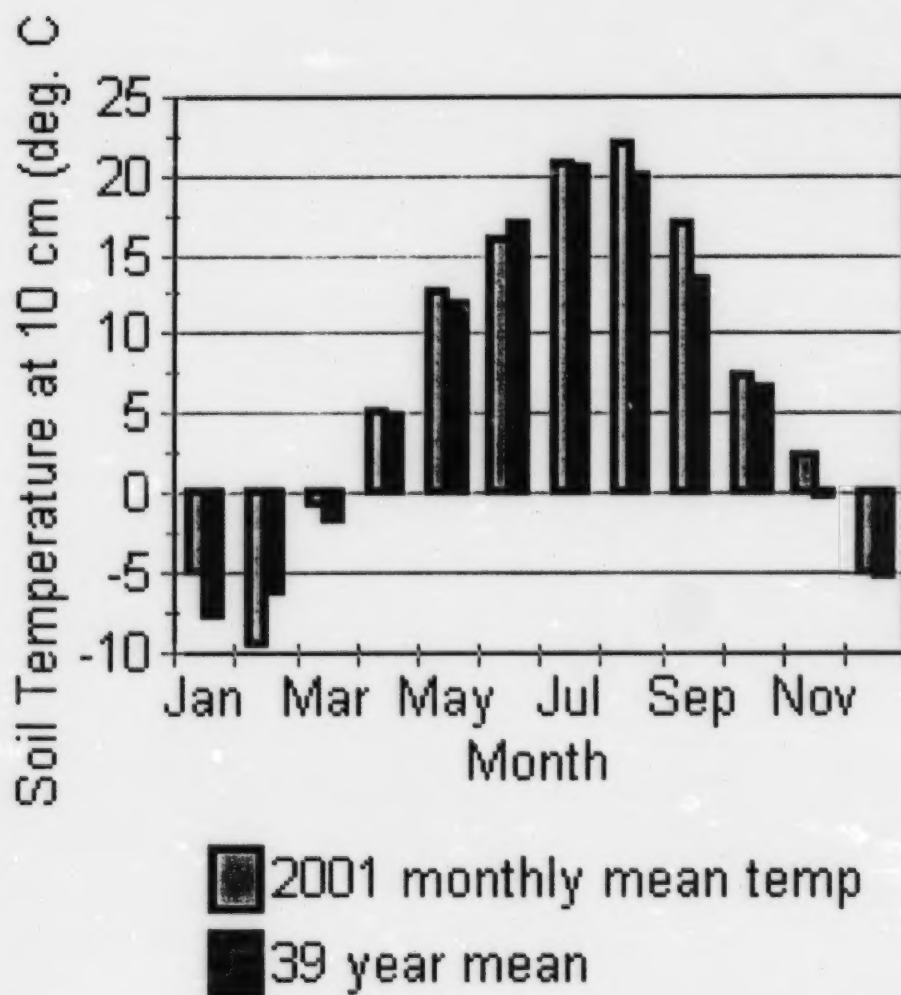


Figure 3e: Mean monthly soil temperature at depth of 10 cm for 2001.



Literature Cited:

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(Ciii)

Seed Harvesting Techniques Effect on Winterfat Production

Objective: to determine the effect of various harvesting methods on the seed yield of winterfat.

Methods and Materials:

This study will determine the effect of various harvesting methods on the seed yield of winterfat. Treatments will be superimposed in a factorial complete randomized block design on plants that have established in a nursery at the Semiarid Prairie Agricultural Research Centre for the development of a winterfat ecovar. The harvesting methods to be assessed include: (1) as a hand harvest control, the most common method presently used. (2) A simulation of combining (sickling) at 50% ripe seed stage of growth, a method used in New Mexico with larger shrubs than found here, will be the second method. (3) The third method will be a vacuum, to emulate equipment already available for insect harvesting. The vacuum method will take advantage of the natural ability of the seed to distribute itself with the wind. (4) The fourth and final treatment will use a flail-type seed stripper again at 50% seed ripe, a device which is commonly utilized for native seed harvest. Data collection will determine (1) the most rapid and economical method, (2) the effect of the various harvesting methods on the individual plants will also be examined. The third comparison will be between plants growing in a weed barrier matting and uncovered soil. This will require usage of the same plants over a three year period to determine the cumulative effects. Crop data will include seed harvest yields, plant height, basal cover, canopy cover, germination of harvested seed, and meteorological information.

Results and Discussion:

1997 Data

Type of soil covering did not have a statistically detectable effect but the plants in the weed barrier did produce more seed in 1997 (Table 1). This may have been due to decreased weed competition and increased soil moisture conservation under the matting.

Method of harvesting had a large impact on the amount of seed obtained. All harvesting techniques were significantly different from each other. The seed obtained with each techniques resulted in the following ranking in 1997: Vacuum>Hand Stripping>Flail>Sickle (Table 1). Flail harvester tended to throw seed forward as a result very little seed was obtained.

As would be expected harvesting techniques show no differences in effects on canopy cover, basal cover or plant height, 1997 being the baseline year.

1998 Data

Overall seed yields for 1998 (Table 2) were less than yields for 1997 (Table 1). This was due in part to the increased stress the plants encountered in 1998. The plants were observed to have two seed sets with a large number of aborted flowers in between. The seeds were aborted during the heat of late July and August (Figure 2). This was also the period of the greatest moisture deficits (Figure 1).

Harvesting occurred over three dates 28 August, 9 and 15 October. Some unripened seed

remained after the final date but early snowfall prevented further collection. One plant which had been harvested via the sickle method had died and was replaced with a randomly selected plant.

Yields per plant were both higher for seed and inert trash (twigs, leaves, etc.) For plants located on in the weed barrier fabric in contrast to plants located in uncovered soil. The seed yields were significantly higher statistically. Although not statistically higher plants within the weed barrier did have greater canopy cover and plant height. (Table 2)

There were no statistically superior harvesting technique for seed yield but the vacuum and sickle had the highest amounts of additional material and were statistically significant. The less damaging techniques (vacuum and hand stripping) had the largest plants while the damaging techniques (flailing and sickling) had smaller plants. Sickling may have stimulated the plants for growth but failed to stimulate seed production. The plants sickled last year recovered the 15 to 30 cm of material removed last year plus the additional growth this year.

1999 Data

Seed harvest occurred 6, 8 to 10 and 27 October. Wind tended to be a problem during the harvesting procedure.

Seed yield continued to drop and as did fall moisture (Section Cii Figure 1c). Plants growing within the weed barrier continued to provide the most seed and biomass production possibly due to improved moisture environment. The impact of moisture on seed production needs to be examined in more detail.

Hand stripping and vacuum harvest techniques continue to provide the most seed with larger plants. Vacuum harvest also yielded a greater amount of trash than hand harvest but considerably less than sickle harvest. A part of the reduction in seed yield for the harvest technique was due to loss of seed due to winds during harvesting. Despite substantial removal of plant material with sickling technique there is not a significant reduction in plant biomass. This indicates an ability for the plant to have enhanced growth when vegetative material is removed. This increase in vegetative growth also appears to decrease seed yield.

2000 Data (Table 4)

Seed harvest dates were 22 August, 15 September, 27 September, 28 September, 10 October, 12 October, 17 October, 19 October, 24 and 25 October. The increase in harvest is an indication of efforts made to recover seed prior to loss via the wind.

Plants growing in the weed barrier had higher trash yield, seed yield, canopy cover, basal cover and plant height. The weed barrier had a positive effect on seed and plant production. The greater trash recovery resulted from retention of material on the weed without loss to decay or removal via wind or water action.

Hand stripping and vacuum harvest techniques continue to provide the most seed with larger plants with hand stripping being the better method. Vacuum harvest also yielded a greater amount of trash than hand harvest but less than sickle harvest. A part of the reduction in seed yield for the harvest technique was due to loss of seed again due to winds during harvesting. With substantial removal of plant material with sickling technique there is a significant reduction in plant biomass after 4 years. The increased vegetative growth also appears to decrease seed yield.

Sickling continues to result in greater plant losses.

Combined Years

Table 5 provides the results for statistical analysis for combined years. 1997 was not included in the analysis but by comparing Tables 1 and 5 there trends are already event in the first year. The years had significantly different seed yields only. This could be attributed to factors the aging stand and declining moisture availability as evidenced in the meteorological data. Although the year appeared to have no impact on plant height, basal or canopy cover measurements. Suggesting seed yield are more sensitive to climatic changes. The weed barrier influenced all factors measured. Plants grown in the barrier having greater growth (seed yield, plant height, canopy and basal cover). The weed barrier changed the micro-environment for the better possibly by decreased weed competition, increased heat irradiation from surface, increased soil moisture capture. Harvest methods which decreased damage (vacuum, hand stripping) to the plant had greater seed yield and growth. Although the vacuum harvesting and sickle also resulted in increased trash there was only increased seed yield with the vacuum. This signifies continued growth for plants sickled but at the cost of seed production.

Conclusion

The data supports use of weed barrier fabric for increased seed and plant production. The harvesting techniques can be ranked for seed yield as follows: vaccuum>hand stripping>flail>sickling. This may be due to increased damage to plants resulting in a shift of resources from seed production to plant biomass. Seed production appears to be sensitive to climatic conditions and should be further investigated.

Table 1: Winterfat seed harvest method effect on seed yield, canopy cover, basal cover and plant height data for 1997 harvest. Statistical analysis performed on square root plus one transform to decrease variability. Reported values converted from square root plus one transform.

Factor	Yield (gm plant ⁻¹)	Canopy Cover (cm)	Basal Cover (cm)	Plant Height (cm)
Soil Covering				
Weed Barrier	15.2	39.4	14.6	42.7
None	10.8	35.8	13.1	40.9
Harvester				
Vacuum	24.8	33.6	11.5	41.4
Hand Stripper	17.7	37.7	16.6	40.3
Flail	4.3	37.2	16.3	41.7
Sickle	2.9	41.7	10.9	43.9
CV (%)	33.3	26.9	22.7	9.9
Contrast				
Vacuum vs Hand, Flail, Sickle	s ^a	ns ^b	ns	ns
Hand vs Flail, Sickle	s	ns	ns	ns
Flail vs Sickle	s	ns	ns	ns

^a - Statistically significant (P>0.01), ^b - Not statistically significant (P>0.05).

Table 2: Winterfat seed harvest method effect on seed yield, canopy cover, basal cover and plant height data for 1998 harvest. Statistical analysis performed on square root plus one transform to decrease variability. Reported values converted from square root plus one transform.

Factor	Seed Yield (gm plant ⁻¹)	Trash Yield (gm plant ⁻¹)	Canopy Cover (cm)	Basal Cover (cm)	Plant Height (cm)
Soil Covering					
Weed Barrier	12.9*	53.9	51.5	27.0	46.5
None	3.5	37.7	45.8	28.0	43.0
Harvester					
Vacuum	11.0	38.3	53.5	29.0	47.0
Hand Stripper	12.2	14.5	60.5	42.0	47.9
Flail	3.6	21.9	41.5	18.0	39.6
Sickle	6.9	108.6	39.0	21.0	44.4
CV (%)	45.6	37.6	15.6	28.0	9.1
Contrast					
Vacuum vs Hand, Flail, Sickle	ns	s	s	s	ns
Hand vs Flail, Sickle	ns	ns	ns	s	s
Flail vs Sickle	ns	s	s	ns	ns

*s - Statistically significant (P>0.05), ns - Not statistically significant (P>0.05).

Table 3: Winterfat seed harvest method effect on seed yield, canopy cover, basal cover and plant height data for 1999 harvest. Statistical analysis performed on square root plus one transform to decrease variability. Reported values converted from square root plus one transform.

Factor	Seed Yield (gm plant ⁻¹)	Trash Yield (gm plant ⁻¹)	Canopy Cover (cm)	Basal Cover (cm)	Plant Height (cm)
Soil Covering					
Weed Barrier	6.7*	60.5	31.3	20.1	50.1*
None	1.0	15.8	22.5	12.6	43.5
Harvester					
Vacuum	3.0	30.6	32.5	21.8	49.2
Hand Stripper	5.7	15.3	33.5	20.5	47.6
Flail	0.4	5.4	18.8	10.0	44.8
Sickle	1.9	92.1	23.0	13.3	45.4
CV (%)	70.9	49.9	27.8	36.2	9.0
Contrast					
Vacuum vs Hand, Flail, Sickle	s	ns	ns	ns	ns
Hand vs Flail, Sickle	ns	ns	s	ns	ns
Flail vs Sickle	ns	s	ns	ns	ns

*,s - Statistically significant (P>0.05), ns - Not statistically significant (P>0.05).

Table 4: Winterfat seed harvest method effect on seed yield, canopy cover, basal cover and plant height data for 2000 harvest. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been back-transformed.

Factor	Seed Yield (gm plant ⁻¹)	Trash Yield (gm plant ⁻¹)	Canopy Cover (cm)	Basal Cover (cm)	Plant Height (cm)
Soil Covering					
Weed Barrier	2.1*	33.4	31.7	21.9*	48.7*
None	0.4	17.2	25.9	15.7	40.8
Harvester					
Vacuum	1.4	52.3	29.5	20.8	46.4
Hand Stripper	3.0	8.5	38.8	28.0	47.2
Flail	0.1	7.7	25.8	15.0	46.6
Sickle	0.4	32.6	21.2	11.4	38.8
CV (%)	34.1	49.6	18.6	24.1	11.6
Contrast					
Vacuum vs Hand, Flail, Sickle	ns	s	ns	ns	ns
Hand vs Flail, Sickle	s	ns	s	s	ns
Flail vs Sickle	ns	s	s	s	ns

*.s - Statistically significant ($P > 0.05$), ns - Not statistically significant ($P > 0.05$).

Table 5: Winterfat seed harvest method effect on seed yield, canopy cover, basal cover and plant height data for all years combined. 1997 data was not included due to data collection changes. Statistical analysis performed on square root plus one transform to decrease variability. Reported values have been back-transformed.

Factor	Seed Yield (gm plant ⁻¹)	Trash Yield (gm plant ⁻¹)	Canopy Cover (cm)	Basal Cover (cm)	Plant Height (cm)
<u>Year</u>					
1998	8.5	44.4	24.3	13.8	44.7
1999	2.9	39.4	26.9	16.4	46.8
2000	1.5	26.5	27.5	18.1	45.3
<u>Soil Covering</u>					
Weed Barrier	6.0*	47.6*	29.0*	18.1*	48.4*
None	1.7	21.6	23.5	14.0	42.5
<u>Harvester</u>					
Vacuum	4.7	37.8	29.6	19.0	47.6
Hand Stripper	6.4	11.9	34.2	23.2	47.6
Flail	1.3	11.2	21.8	11.3	43.7
Sickle	3.0	77.5	19.5	10.8	42.3
<u>CV (%)</u>	45.9	51.7	23.8	30.3	10.1
<u>Contrast</u>					
1997 vs rest	NA	ns	ns	ns	ns
1998 vs 1999,2000	s	ns	ns	ns	ns
1999 vs 2000	s	ns	ns	ns	ns
Vacuum vs Hand, Flail, Sickle	s	ns	s	ns	ns
Hand vs Flail, Sickle	s	s	s	s	ns
Flail vs Sickle	ns	s	ns	ns	ns

*,s - Statistically significant (P>0.05), ns - Not statistically significant (P>0.05).
NA - not applicable

(Civ)

Weed Control for Winterfat

Objective: to rapidly determine a potential herbicide to control weeds in winterfat stands.

Methods and Materials:

Three possible herbicides were identified for potential control of weeds in winterfat stands. Plots seeded in spring of 1997 had three spray plots superimposed. The three spray plots ran in a east-west direction. Cobutox 600 (2,4-DB) was applied on 11 June 1998 at a rate of 0.8 l/ac. Basagran (bentazon) was applied on 15 June 1998 at a rate of 0.8 l/ac. Roundup (glyphosate) was applied on 24 June 1998 at a rate of 0.3 l/ac. All spray application occurred on days which were clear, winds did not exceed 5km/hr and the temperature at time of application did not exceed 15 degrees Celsius. Winterfat plants ranged in size from 15 cm to 45 cm. A solid weed cover was present with plant height averaging 15 cm. Weed species included *Chenopodium album* (lamb's quarter), *Monolepis nuttalliana* (spear-leaved goosefoot), *Amaranthus graecizans* (prostrate amaranth), *A. retroflexus* (red-root pigweed), *Descuriana sophia* (flixweed), *Lepidium* spp. (Pepper grass), and *Thlaspi arvense* (stinkweed) to name the more common species. The spray strips were checked for impact on winterfat plants 3 July 1998.

Results and Discussion:

Cobutox caused a great deal of distortion of the upper portion of the winterfat plant. There was also a great deal of splitting of the cambium in the distorted ends. No winterfat plants were killed.

Basagran caused less distortion of the upper portion of the winterfat with no apparent splitting of the cambium. No winterfat plants were killed.

Roundup appeared to cause discoloration on approximately 5% of the plants with no other noticeable effect.

Weed control appeared to be better with the Roundup treatment. The lack of effect on the winterfat plants may be due to the high degree of pubescence on the plants enabling them to prevent contact with leaf surface.

The results suggest Roundup should provide adequate weed control with minimal damage to winterfat plants at this low rate. For recommendations to be made for appropriate herbicide usage with a winterfat crop a properly replicated test with additional herbicide choices must be performed.

Milestones:**Activities for 1996:**

- 1) A literature search was done for information pertaining to seeding and harvesting of winterfat.
- 2) Seed source was found for spring 1997 seeding and 25 lbs. were purchased for delivery prior to 1 April 1997.
- 3) Process has begun for hiring of technical assistant, to be in place 1 April 1997.

Activities for 1997:

- 1) Hire technical help. Due to first candidate leaving after spring work started an unanticipated delay occurred in the seeding. Seeding continued as soon as new candidate was in place. No delays for seeding of fall expected thus eliminating seeding date X seeding method interaction confounding.
- 2) Seed winterfat using seeders described in proposal. Fertilizer used was lime. Lime was selected to improve flow of seed and to replace calcium reported to be supplied by bracts.
- 3) Collection of spring and late summer seedling counts, year end plant heights, and soil moisture data.
- 4) Harvest preselected winterfat plants from station nursery as described in proposal. By August plants in the nursery were setting seed. Anticipated date of harvest is the second week of September.

Deviation -due to failure of air seeder to deliver seed air seeder treatments will be replaced with broadcast seeding without packing.

Activities for 1998:

- 1) Seed winterfat seed in spring 1998.
- 2) Collect data from emerging seedlings from the fall 1997 and spring 1998 seedings.
- 3) Assess winter survival and production of spring 1997 seeding.
- 4) Collect plant growth data from seed nursery plants.
- 5) Harvest winterfat seed in fall.

Activities for 1999:

- 1) Seed winterfat seed in spring 1999.
- 2) Collect data from emerging seedlings from the fall 1998 and spring 1999 seedings.
- 3) Assess winter survival and production of spring 1998 seeding.
- 4) Collect plant growth data from seed nursery plants.
- 5) Harvest winterfat seed in fall.

Activities for 2000:

- 1) Seed winterfat seed in spring 2000.
- 2) Collect data from emerging seedlings from the fall 1999 and spring 2000 seedings.
- 3) Assess winter survival and production of spring 1999 seeding.
- 4) Collect plant growth data from seed nursery plants.
- 5) Harvest winterfat seed in fall.

Activities for 2001:

- 1) Collect data from emerging seedlings from the fall 2000 seeding.
- 2) Assess winter survival and production of spring 1999 seeding.
- 3) Summarize and complete final report 1 Dec 2001.

(D) Personnel: EG-01 PJ Coward 05 May to 05 June 1997

JM Bolton 05 June 1997 to ---

Note: First candidate quit to start another position requiring a second individual be found to continue the work. A problem which should not occur in the future.

(E) Equipment: None

(F) Project developed materials: None

(G) Project Photos: 97-1 nursery plots for harvest study, 97-2 vacuum method, 97-3 hand strip method, 97-4 plant before flail harvest, 97-5 plant after flail harvest.

(H) Acknowledgment: Funding was listed in: 1) subsequent funding applications, 2) four presentations to producer groups, 3) two workshop presentations, 3) two research newsletter (which was reprinted by a number of producer papers), 4) project support in SPARC - AAFC program review, 5) International Pasture Ecology Newsletter and 6) two ADF proposals. For Soils and Crops 2000 poster was presented detailing harvest data. Poster for 2001 AGM-SRM seed harvest data was presented and received with a high degree of interest. Requests for copies of scientific paper were received as a result. Publication of results in a recognized scientific journal is anticipated.